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(54) Abstract Title
Heat exchanger

(57) A heat exchanger comprises at least one layer (13, 33) of substantially parallel conduits laid on a base plate (11). Two sidewalls (12A, 12B) are positioned on the base plate (11) with the conduits (13) lying between and substantially parallel to the sidewalls (12A, 12B). The sidewalls are formed by stacking a plurality of flat shims (12C, 12D, 12E) on the base plate (11) and the height of the sidewalls (12A, 12B) so formed is such that the conduits (13) extend above the sidewalls (12A, 12B). A top plate (20, 40) is positioned on the so-extending upper surfaces of the conduits (13, 33). Heat and loading are applied to the composite structure so formed while in a vacuum to deform the conduits (13, 33) to reduce their height, whereby the conduits bond to the plates (11, 20, 40). The conduits may be arranged in a plurality of groups (figure 5) separated by spacer bars (206).

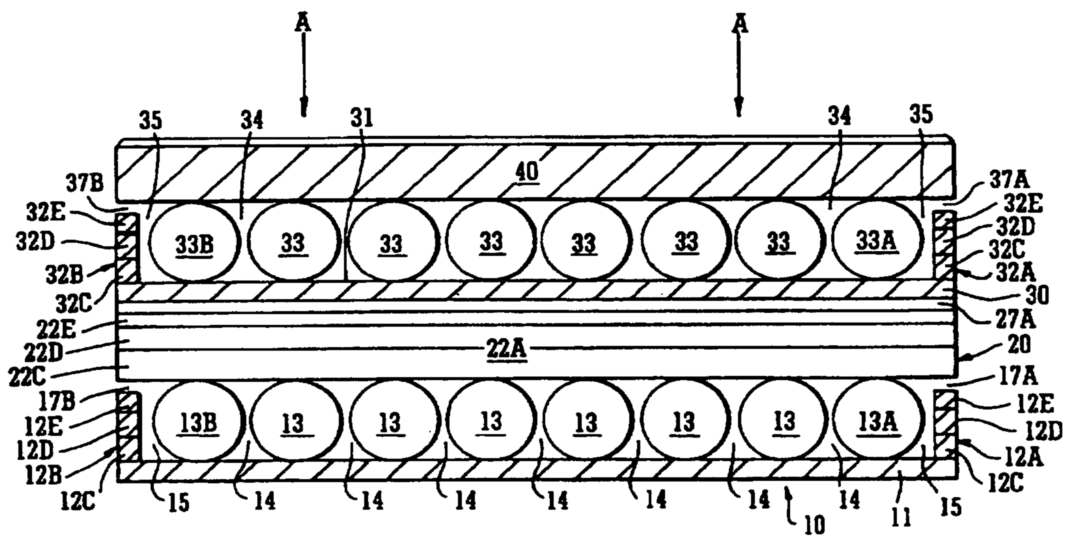
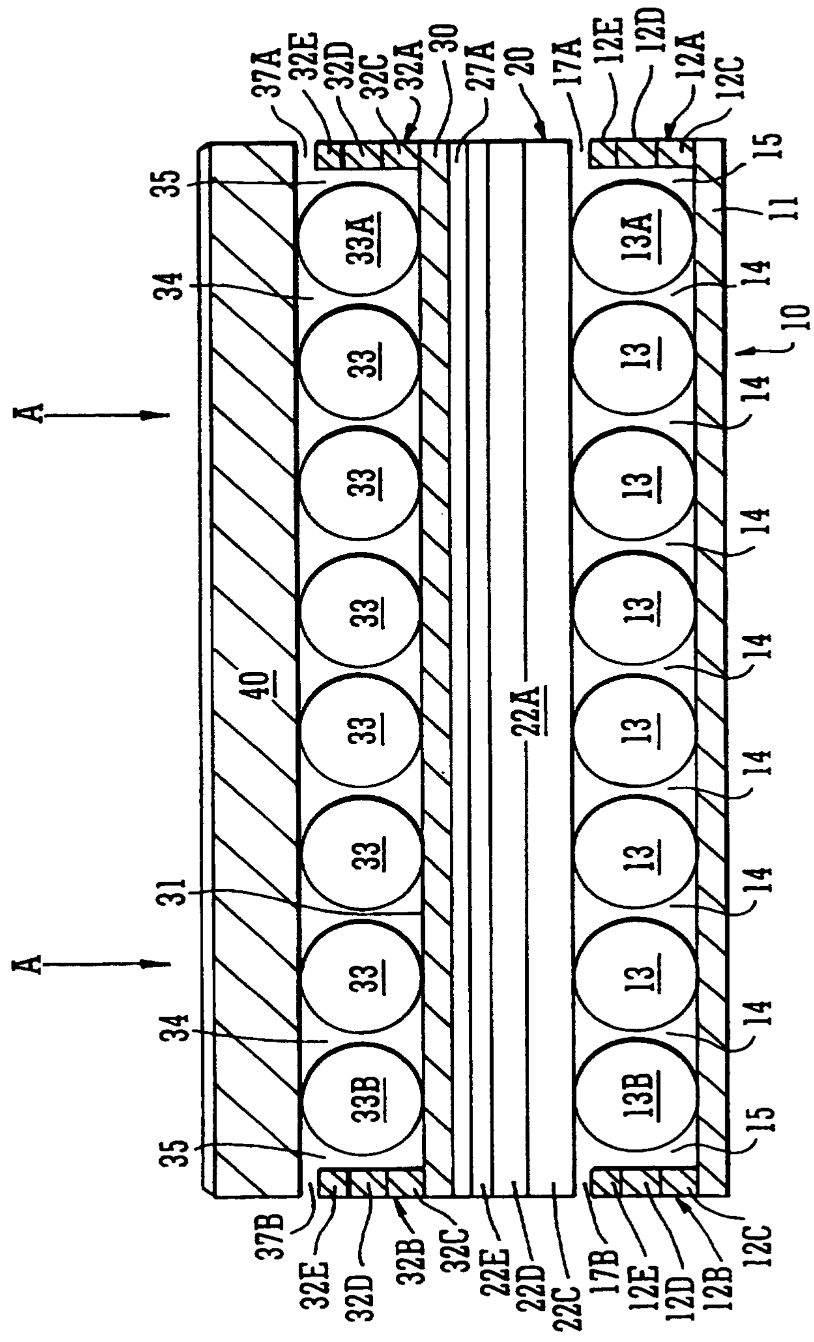


FIG. 1

GB 2 328 732 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.
The claims were filed later than th filing date within the period prescribed by Rule 25(1) of the Patents Rules 1995
The print reflects an assignment of the application under the provisions of Section 30 of the Patents Act 1977.


37A
32E
32D
32C
32A
30
27A
20
17A
12E
12D
12A
12C
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11
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35
34
33A
33
13A
13
14
A
40
22A
31
33B
13B
37B
32B
22E
22D
22C
17B
12B

FIG. 1

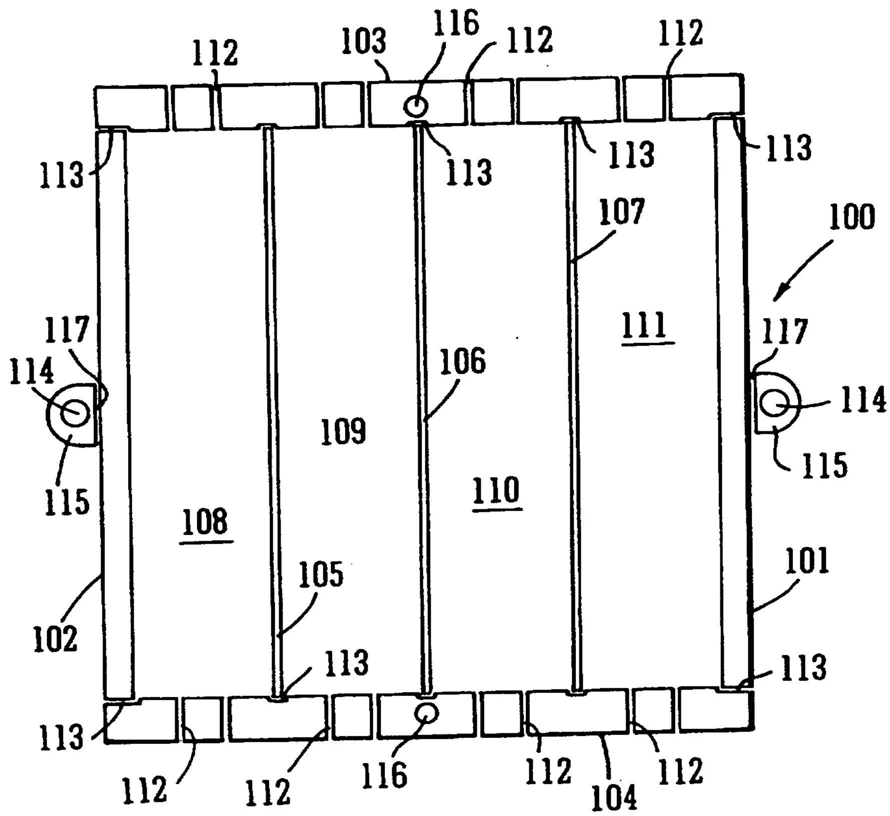

FIG. 2

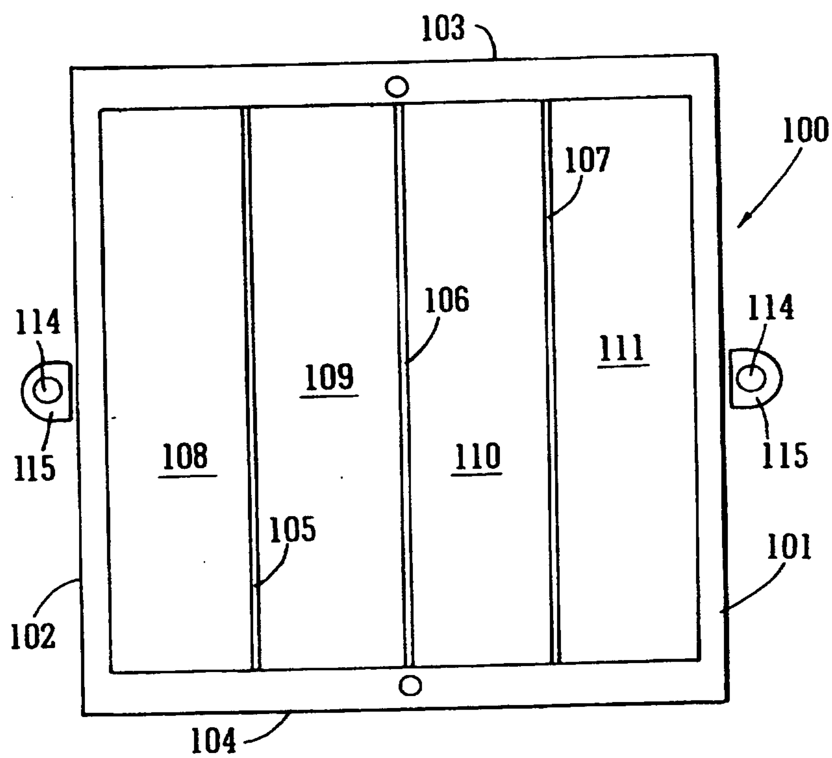

FIG. 3

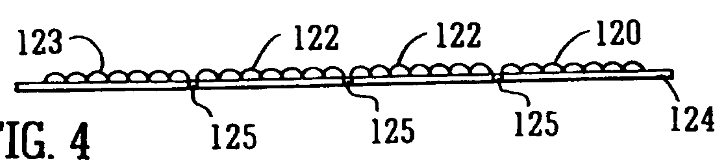

FIG. 4

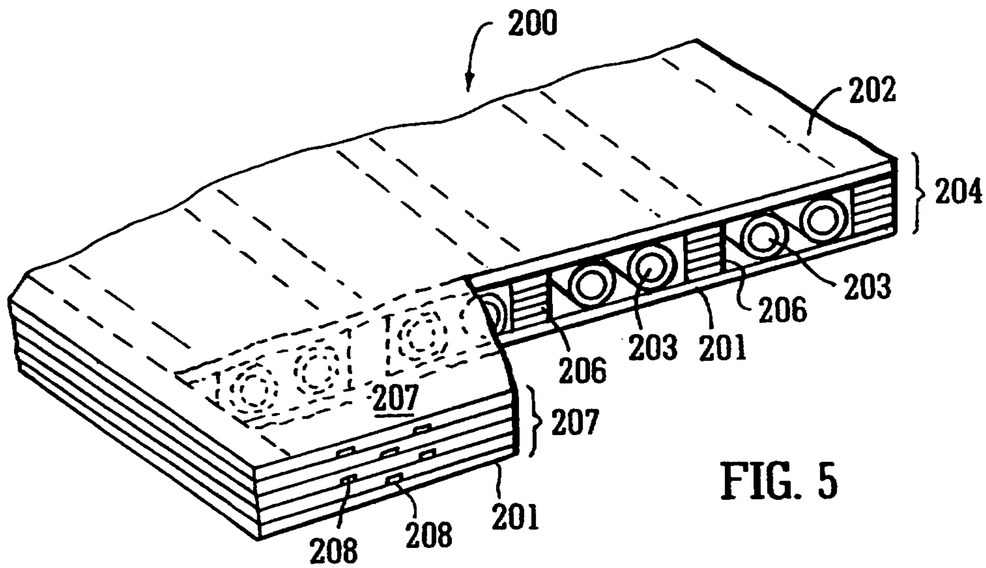
200
202
204
203
206
203
206
203
201
207
207
201
208
208

FIG. 5

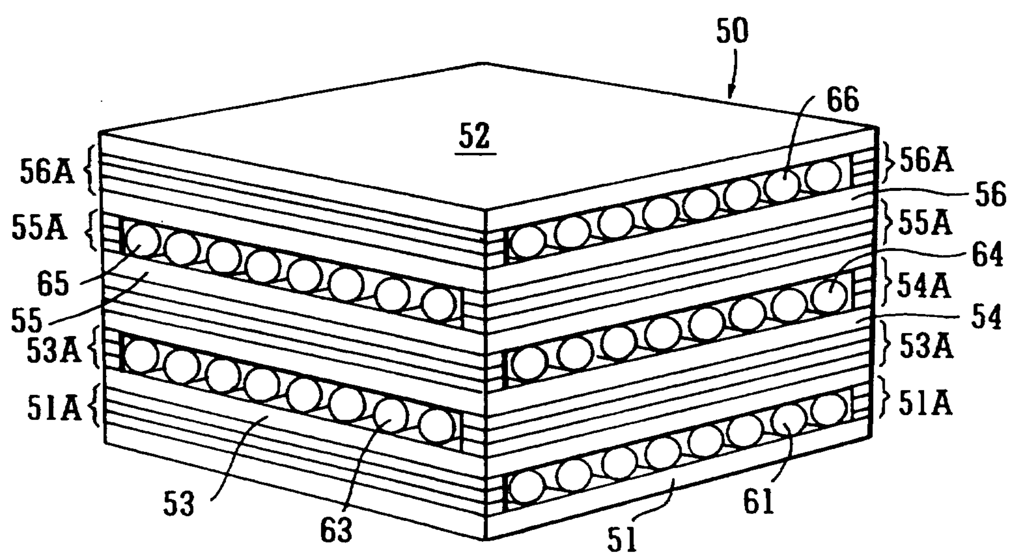
50
66
52
56A
56A
56
55A
55A
64
65
54A
55
54
53A
53A
51A
51A
53
63
61
51

FIG. 6

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HEAT EXCHANGER

This invention relates to a heat exchanger and, particularly, to a heat exchanger formed by diffusion bonding.

- It has been proposed to manufacture a heat exchanger in which fluid passageways are created, for example, in two adjacent metal sheets by forming bonds between the sheets along spaced parallel weld or diffusion bonded lines and then super-plastically deforming the material of the bonded sheets to form a passageway between each adjacent pair of bond lines.

It has also been proposed in our copending international patent application number PCT/GB97/01392 to make a heat exchanger comprising at least two layers of tubes in which a first layer of substantially parallel tubes is laid on a base plate, two sidewalls are positioned on the base plate with the tubes lying between and substantially parallel to the sidewalls, at least one further layer of substantially parallel tubes is positioned above the first layer, each further layer resting on an intermediate plate and between two parallel sidewalls of the intermediate plate, the distance between the sidewalls of each plate being greater than the sum of the measured outside diameters of the tubes of its respective layer by an amount predetermined by calculation from the sum of such diameters and the height of the sidewalls being such that the tubes of each layer extend above their respective sidewalls whereby each intermediate plate rests on the tubes of the layer immediately below, a top plate being positioned on the uppermost layer of tubes. Heat and loading are then applied to the composite structure so formed whilst in a vacuum to deform the tubes thereby reducing the height of the tubes, whereby tubes adjacent plates

are bonded to said plates and the tops of the sidewalls bond to the plate above. The tubes may also bond to each other. They are normally of circular cross-section initially and will deform to slightly oval shape during the process.

The present invention aims to provide a further improved method of making a heat exchanger.

Accordingly, in one aspect the invention provides a method of making a heat exchanger comprising at least one layer of conduits in which a layer of substantially parallel conduits is laid on a base plate with said conduits having a height dimension defined as extending perpendicular to the plane of the base plate, two sidewalls are positioned on the base plate with the conduits lying between and substantially parallel to the sidewalls, the sidewalls being formed by stacking a plurality of flat shims on the base plate and the height of the sidewalls so formed is such that the height of the conduits extends above the sidewalls, and a top plate is positioned on the so-extending upper surfaces of the conduits, heat and loading are applied to the composite structure so formed while in a vacuum to deform the conduits to reduce their height, and to bond the conduits to the plates.

The conduits adjacent the sidewalls may also bond to the sidewalls.

In another aspect the invention provides a heat exchanger comprising at least one layer of substantially parallel conduits, the layer lying on a base plate and being covered by a top plate, the conduits lying between and substantially parallel to sidewalls, the sidewalls comprising a stack of a plurality of flat shims on the base plate, the

shims of each stack being bonded together and the conduits and sidewalls being bonded to the base plate and top plate.

The sidewalls may also be bonded to adjacent conduits. Adjacent conduits may also be bonded together.

In one embodiment the conduits may be a plurality of tubes, which will normally be of circular cross-section initially and will deform to slightly oval shape during the deformation process. In this embodiment the distance between the sidewalls may be greater than the sum of the outside measured diameters of the tubes by an amount predetermined by calculation from the sum of such diameters and the tubes may bond to each other during the process.

In a second embodiment the conduits may be provided by the corrugations of a corrugated sheet positioned between a base plate and a top plate. In this embodiment, the distance between the sidewalls may be greater than the transverse extent of the corrugated sheet between the sidewalls by an amount similarly predetermined by calculation so that the corrugated sheet may contact and be bonded to the sidewalls during the bonding process.

The skilled man will readily be able to calculate the aforesaid predetermined amount for the particular tubes or corrugated sheet used. Similarly he will be able to calculate the amount by which the sidewalls should extend above the conduits.

In another aspect of the invention, intermediate walls or spacer bars are positioned on the base plate to lie between groups of conduits. The spacer bars extend parallel to the conduits and to the sidewalls and may be built up from a plurality of flat shims of thicknesses exactly equivalent to the sidewall shims so as to extend above the conduits by

the same amount as the sidewalls. By this means the loading applied to the composite structure during the bonding process is maintained evenly on the conduits.

Accordingly, the invention provides in a yet further aspect a heat exchanger comprising at least one layer of substantially parallel conduits, the layer lying on a base plate and being covered by a top plate, the conduits lying between and substantially parallel to sidewalls, the conduits of the layer being in a plurality of groups of conduits, adjacent groups being separated by a spacer bar extending substantially parallel to the sidewalls, the spacer bars and sidewalls being of the same height and the conduits, sidewalls and spacer bars being bonded to the top and bottom plates.

The sidewalls and spacer bars may be bonded to adjacent conduits.

Both the sidewalls and spacer bars may be built up from flat shims.

Conveniently the sidewall shims and spacer bar shims can be integrally formed as composite shim units whereby the sidewalls and spacer bars are built up by stacking a plurality of composite flat shims.

The shims used may conveniently be formed from rolled sheet of the desired material, e.g. stainless steel, nickel-based alloys, brass or copper. Such rolled sheet is available in a range of thicknesses to a high degree of tolerance, i.e. the thickness of the sheet is constant to high tolerance levels throughout the sheet. Thus any desired height of sidewall and spacer bar can be built up accurately to provide flat-topped sidewalls and spacer bars using a plurality of shims formed from sheets of different thicknesses. For example, shims of various thicknesses

from 0.1mm to 0.5mm or higher may be stacked to reach a desired height to extend above a layer of conduits of height, say from 2mm to 25mm or more. It will be appreciated that the avoidance or minimising of any deviation from perfectly planar or flat tops to the sidewalls and spacer bars greatly improves the integrity of the bonded structure.

The composite structure formed by positioning the conduits between a base plate and a top plate preferably contains a plurality of layers of conduits. Thus after a first layer of conduits has been positioned on the base plate and the sidewall shims and spacer bar shims (where used) have been built to the desired height, an intermediate plate is positioned to rest on the sidewalls (and spacer bars) and a further layer of conduits is then positioned on the intermediate plate. Sidewalls (and spacer bars) may then be built up using further shims to extend above the further layer of conduits and this process may be continued until the desired number of layers has been achieved and the top plate is then added.

Preferably the sidewalls are spaced from their adjacent conduits and, where the conduits are tubes, each tube may be spaced from its neighbour in that layer and the spacings or gaps may all be substantially equal. However, this is not essential and each sidewall may, for example, contact its adjacent conduit in the composite structure before pressure is applied provided that the overall spacings are such that the gaps will close and bond the product effectively without undue distortion. The plates, shims and conduits will normally be of the same material and, where of metal, the bonding is preferably carried out under conditions of temperature and loading and in a vacuum chamber to effect diffusion bonding.

It will be appreciated that the temperature and pressure required to provide adequate bonding of the various components of the composite structure will depend on the materials from which the conduits and plates are made and on the dimensions used, e.g. tube diameters and wall thickness and plate thickness. However, the skilled man of the art will readily be able to determine appropriate conditions for his particular circumstances.

Moreover, it will also be appreciated that the spacings of the tubes and the relative heights of the tubes and sidewalls must be carefully determined for a particular composite structure. Again the skilled man can readily determine the appropriate requirements. The bore of the conduits is determined by the heat transfer and pressure drop requirements of the heat exchanger, the wall thickness of the conduits is determined by the ruling pressure in use and the required tolerances can then be readily determined and appropriate tubing or corrugated sheet obtained to meet those requirements.

For example, with stainless steel tubes of 6mm outside diameter, calculations suggest that the spacings between adjacent parallel tubes and between outer tubes and their respective sidewalls are around 0.2mm so that the total spacing across an array of n tubes in a layer will be (n+1) x 0.2mm. For such tubes, the sidewalls may be 0.1m less in height than the outside diameter of the tubes.

The plates may be flat plates or some of them may be contoured, e.g. corrugated. Thus, for example, particularly where the conduits are tubes, the base plate and any intermediate plates may have corrugations defined to provide the pre-determined spacings between individual tubes positioned to lie in the valleys of the corrugations. Alternatively, where

flat plates are used, the tubes may be positioned as required on the flat surface to provide the necessary gaps. As indicated above, it may be preferred to provide substantially equal gaps between the tubes and between the outermost tubes and the sidewalls. However, this is not essential and irregular spacings may be used provided that the application of pressure to the composite structure causes movement of the tubes to completely fill the gap between the sidewalls with deformed, substantially equi-spaced tubes.

It is preferred that alternate layers of parallel conduits extend transversely to each other (and, hence, that the sidewalls of one layer extend transversely to the sidewalls of each immediate adjacent layer.). However, this is not essential and, if desired, adjacent layers of conduits may extend parallel to each other or a mixture of adjacent parallel and adjacent transverse conduits may be utilised depending on the desired final configuration.

Thus any stream of fluid passing through the heat exchanger may be formed by more than one layer of parallel conduits and an adjacent stream at right angles to the first stream may similarly be formed of more than one layer of parallel conduits. In such an embodiment the conduits in different layers of a single stream may, if desired, be of different bore, e.g. different tube diameters. By this means greater flexibility can be achieved for the flow area that is required for each stream.

The invention is not restricted to, e.g., tube and plate configurations which provide a simple cross-flow heat exchanger in which one fluid passes in a single direction from one side of the heat exchanger to the other, whilst a second fluid in an adjacent layer passes

in a single direction at right angles to that of the first fluid. With the present invention the conduits for one fluid may change direction towards one or both sides of the heat exchanger, typically through a right-angle, so as to provide configurations, e.g. in which one fluid enters and leaves the heat exchanger on the same side. In such instances the conduits are preformed with their right angles adjacent one or both ends before being assembled together such that they are parallel to one another along both of their respective directions. In this way configurations such as those known as "cross-contra" etc. can be formed. In these cases, there are more than two sidewalls.

The required loading may be applied, for example, by a hydraulic ram in a heated vacuum chamber so that pressure can be progressively applied to the composite structure to achieve the desired diffusion bonding. Thus the load applied is initially confined to the protruding conduits which will deform sufficiently for the gaps to close. The plates will then come in contact with the sidewalls (and spacer bars) below and a further increase in load will increase pressure at the contact points between the conduits and the plates and spacer bars, the conduits and the sidewalls, spacer bars and the sidewalls and the plates sufficiently to achieve the minimum required bonding pressures throughout. This condition is held until the diffusion bonding is complete.

The top and base plates should be of sufficient thickness to allow subsequent welding of header tanks and/or auxiliary equipment needing to be attached to the bonded structure. These attachments may also, if desired, be built up from stacked shims which become bonded together during the manufacturing process.

The heat exchangers of the invention will usually be formed using rectangular plates to provide a parallelepiped composite structure. The sidewall shims, therefore, may conveniently be formed, e.g. by etching, from-suitable rolled sheet, as rectangular annuli or gaskets, two opposite first and second sides of the rectangle providing the two desired sidewall shims between which the conduits are to lie. The two other, third and fourth, opposite sides of the rectangle provide the means whereby integral spacer bars shims may be formed, extending from and between those third and fourth sides parallel to the sidewall shims.

Conveniently the third and fourth sides of the rectangular shims may also be formed to have areas of reduced thickness to correspond to the positions of the conduits in the composite structure to be bonded. By this means the desired application of vacuum to the tubes during bonding can still be achieved.

The shims may also be formed to have location lugs and lines of weakness whereby the third and fourth sides of all the stacked shims may be readily broken off from the finished product after bonding to allow unlimited access to the conduits.

Embodiments of the invention will now be described by way of example only with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic representation in transverse cross-section of a composite structure of the invention prior to bonding;

Figure 2 is a plan view of an integral sidewall/spacer bar composite shim for use in the invention;

Figure 3 is a plan view showing the opposite face of the composite shim to that shown in Figure 2;

Figure 4 is a diagrammatic representation in side view showing a series of conduits extending above a sidewall;

Figure 5 is a fragmentary perspective view of a product of the invention; and

Figure 6 is a perspective view of another product of the invention.

In Figure 1, a composite structure 10 for a heat exchanger having three layers of tubes is shown. A base plate 11 of rectangular form has sidewalls 12A and 12B positioned to run the length of its longer sides.

Sidewalls 12A and 12B are each made up, as shown, of three flat shims 12C, 12D and 12E. These shims are each of rectangular plan form having one opposed pair of sides 12C or 12D or 12E and a second pair of opposed sides not visible in the sectional view of Figure 1. (These shims are similar in appearance to the shim described below and shown in Figures 2 and 3 but without the spacer bars of that embodiment.).

A first layer of eight tubes 13 is positioned on base 11. The tubes are of outside diameter, e.g., 6mm and are positioned to run parallel to sidewalls 12A and 12B with gaps 14 of about 0.2mm between adjacent tubes and a gap 15 of about 0.2mm between outer tube 13A and its adjacent sidewall 12A and between outer tube 13B and its adjacent sidewall 12B.

Sidewalls 12A and 12B are about 0.1mm less in height than the outside diameter of the tubes so that the tubes protrude above the sidewalls. An intermediate plate 20 is positioned to rest on the tops of tubes 13. This plate is similar to plate 10 (although it need not be so thick). Two sidewalls, only one of which 22A is shown, are built up on plate 20 from shims 22C, 22D, 22E of the same thickness as shims 12C,

12D and 12E. Plate 20 is positioned so that its sidewalls are transverse to those of base plate 10. A row of eight tubes (not shown) is similarly positioned on intermediate plate 20 with similar spacings to the tubes 13 but with the tubes parallel to sidewall 22A and hence at right angles to the first layer of tubes 13.

Because tubes 13 are taller than sidewalls 12A, 12B, a gap 17A, 17B is provided between the top of sidewalls 12A, 12B respectively and the underside of plate 20.

A further similar intermediate plate 30 is positioned on the tops of the tubes on plate 20. A pair of sidewalls 32A, 32B built up from shims 32C, 32D, 32E is positioned on upper face 31 of plate 30. These sidewalls are positioned to be parallel to sidewalls 12A, 12B and of the base plate 10. A further eight tubes 33 are positioned on face 31 of plate 30 with the same spacing as for the previous layers. Thus there are gaps 34 between adjacent tubes and gaps 35 between outer tube 33A and sidewall 32A and between outer tube 33B and sidewall 32B.

As can be seen, a gap 27A is formed between sidewall 22A and the underside of plate 30. A similar gap (not shown) is, of course, formed between the other sidewall of plate 20 and the underside of plate 30.

A top plate 40 is placed on the tops of tubes 33 whereby a gap 37A, 37B is formed between the tops of sidewalls 32A and 32B respectively and the underside of plate 40.

The composite structure so formed is now ready for pressing, the arrows A in Figure 1 indicating the direction of pressing.

Thus it can be appreciated that successive layers of plates and tubes can be built up with alternate layers of tubes having their

longitudinal axes at right angles to each other until the total desired layer height is achieved. Once assembled, the structure may be placed under a ram system in a heated vacuum chamber and heat and pressure progressively applied.

As indicated above, the load applied is initially confined to the protruding tubes causing them to deform to slightly oval configuration. This process continues until all the tubes have deformed sufficiently for all the gaps (14, 34, etc.) to close and the tubes to come into contact with adjacent parallel tubes of their respective layer. The pressure loading then increases between the tubes and their contacts with the plates. Also at this point in the process, the correct clearances having been allowed for the specific circumstances, the undersides of plates 20, 30 and 40 will have closed gaps 17A, 17B; 27A, 27B and 37A, 37B and will have come into contact with the tops of the sidewalls 12A, 12B; 32A, 32B; etc. The loading is then further increased to ensure bonding throughout the product.

Again, as indicated above, the pressure is held in this stable condition to allow the diffusion bonding process to be completed.

It will be appreciated that the embodiment described with reference to Figure 1 does not include the use of intermediate walls or spacer bars between groups of tubes in each layer. In Figures 2 and 3 is described a composite shim unit whereby desired sidewalls and spacer bars can be built up at the same time.

In Figures 2 and 3 a composite shim unit 100 is rectangular in plan form having a pair of opposed parallel walls 101 and 102 joined by a second pair of opposed parallel walls 103, 104. Sidewalls 101 and 102, when shim 100 is stacked on a base plate with other shims of

similar rectangular configuration, form, together with the corresponding sidewalls of those other shims, the desired sidewalls of a composite structure.

Spacer bar shim portions 105, 106, 107 extend between walls 103 and 104 parallel to sidewalls 101 and 102 and define four cavities 108, 109, 110 and 111 between the sidewalls. Again when shim 100 is stacked with other shims, spacer bar shim portions 105, 106 and 107 stack with corresponding shim portions to form the desired spacer bars and the cavities to contain tubes or other conduits. Such conduits will extend parallel to the sidewalls and spacer bars.

As shown in Figure 2 walls 103 and 104 have vents 112 extending from the exterior of the shim to the interior of the rectangle, i.e. extending into cavities 108, 109, 110 and 111. Vents 112 are formed only partially through the thickness of the walls so that they do not appear in the face of the shim shown in Figure 3. By this means the conduits, e.g. tubes, when fitted into the composite structure are vented through walls 103 and 104 and may, therefore, be evacuated when desired for the bonding operation.

Also as shown in Figure 2, walls 103 and 104 have lines 113 of weakness formed at their junction with walls 101 and 102 and at their junctions with spacer bars 105, 106, 107. These lines of weakness are conveniently provided by reducing the thickness of the shim at these regions. When the components of a heat exchanger made using shims as shown in Figures 2 and 3 have been bonded together, the walls formed by the stacking together of a plurality of shim walls 103 and 104 respectively may then be readily broken off to leave unhindered access

into the conduits of each layer. (This is described in more detail with reference to Figure 5 below.).

As also shown in Figures 2 and 3, location jig holes are provided in each shim wall 101, 102, 103, 104, a hole 114 in each of walls 101 and 102 being provided in an integral lug 115 and a hole 116 in each of walls 103 and 104 being provided through the wall thickness. A stack of shims may thereby conveniently be built up and then held in the desired stacked configuration in a jig.

Lugs 115 are also attached to walls 101 and 102 along a line of weakness 117, see Figure 2, so that the lugs may be readily removed from the final product.

The vent holes and lines of weakness may conveniently be formed as part of the etching process when the shims are etched from sheet material.

In Figure 4, four groups of conduits 120, 121, 122 and 123 are shown partially visible above a wall of a shim 124. This shim will be the uppermost shim of a stack of which the other shims are not shown. In the spaces between the groups of conduits spacer bars 125 will extend between and parallel to the conduits.

In Figure 5 is shown a portion of a bonded heat exchanger 200 of the invention. It comprises a bottom plate 201 and a top plate 202. Groups (pairs) of conduits in the form of tubes 203 extend parallel to a pair of sidewalls 204 and are separated by spacer bars 206. An end wall 207 (one only shown) extends between the sidewalls 204 at each end of the heat exchanger.

As can be seen, each sidewall, end wall and spacer bar is made up of four shims and the end wall 207 has vent holes 208, which extend through the end walls so that the tubes 203 are vented to the exterior of the product.

End wall 207 at each end of the product can be broken off along lines of weakness as discussed above in order to completely expose the ends of the tubes - as shown at the right hand portion of Figure 5.

A different finished product is shown in Figure 6. The heat exchanger unit 50 has a base plate 51, a top plate 52 and four intermediate plate layers 53, 54, 55 and 56. Base plate 51 and intermediate plates 53, 54, 55, 56 each have a pair of sidewalls 51A, 53A, 54A, 55A and 56A respectively each built up from three shims in the manner previously described.

Alternate plates 51, 53, 54, 55 and 56 are positioned at right angles to each other and each plate carries eight parallel tubes 61, 63, 64, 65 and 66 respectively.

The unit is completely bonded together, i.e. the tubes of each layer are bonded to adjacent tubes of that layer and to the plate immediately above and below. The outer tubes of each layer are bonded to their respective sidewalls. The tops of the sidewalls are bonded to the peripheries of their respective plate above.

As can be seen, the ends of the tubes are visible and accessible in the side faces of the unit and may be connected by conventional means as required, to receive their respective fluid flow. Header tanks and

other fitments may be welded to the exposed surfaces of base plate 51 and top plate 52. The tubes are now slightly oval in cross-section.

CLAIMS

1. A method of making a heat exchanger comprising at least one layer of conduits in which a layer of substantially parallel conduits is laid on a base plate, two sidewalls are positioned on the base plate with the conduits lying between and substantially parallel to the sidewalls, the sidewalls being formed by stacking a plurality of flat shims on the base plate and the height of the sidewalls so formed is such that the conduits extend above the sidewalls, and a top plate is positioned on the so-extending upper surfaces of the conduits, heat and loading are applied to the composite structure so formed while in a vacuum to deform the conduits to reduce their height, whereby the conduits bond to the plates.

2. A method according to Claim 1, in which the conduits are provided by a plurality of tubes.

3. A method according to Claim 2 in which the tubes are initially of circular cross-section and are deformed to oval cross-section during the bonding step.

4. A method according to Claim 3, in which the distance between the sidewalls is greater than the sum of the outside diameters of the tubes by an amount predetermined by calculation from the sum of the outside diameters such that the tubes bond to each other as they deform during the bonding step.

5. A method according to Claim 1, in which the conduits are provided by the corrugations of a corrugated sheet positioned between the base plate and the top plate.

6. A method according to Claim 5, in which the distance between the sidewalls is greater than the transverse extent of the corrugated sheet

between the sidewalls by an amount predetermined by calculation such that the corrugated sheet contacts and bonds to the sidewalls during the bonding step.

7. A method according to any preceding claim, in which spacer bars are positioned on the base plate to lie between groups of conduits and to extend parallel to the sidewalls and to the conduits.

8. A method according to Claim 7, in which the spacer bars are built up from a plurality of flat shims to extend above the conduits by the same amount as the sidewalls.

9. A method according to Claim 8, in which the sidewall shims and spacer bar shims are formed as composite shim units.

10. A method according to any preceding claim, in which the shims are formed from rolled sheet.

11. A method according to Claim 10, in which the rolled sheet is of stainless steel, a nickel-based alloy, brass or copper.

12. A method according to any preceding claim, in which after a first layer of conduits has been positioned on the base plate and the shims have been stacked to the desired height, an intermediate plate is positioned to rest on the sidewalls, a further layer of conduits is positioned on the intermediate plate, further sidewalls are built up using further shims to extend above the further layer of conduits and the process is repeated to achieve the desired number of layers of conduits and the top plate is then added.

13. A method according to any preceding claim, in which the bonding is carried out under conditions to achieve diffusion bonding.

14. A method according to any one of Claims 1 to 4 and 7 to 13, in which some at least of the plates have corrugations and the conduits are positioned to lie in the valleys of the corrugations.

15. A method according to any preceding claim, in which a plurality of layers of conduits is formed with adjacent layers of the conduits extending transversely to each other.

16. A method according to any preceding claim, in which the plates are rectangular and the sidewall shims are formed as rectangular annuli.

17. A method according to Claim 16, in which two opposite sides of the rectangular annuli provide the two sidewalls shims between which the conduits are positioned and the two other opposite sides of the rectangular annuli have integrally formed spacer bar shims extending between them.

18. A heat exchanger comprising at least one layer of substantially parallel conduits, the layer lying on a base plate and being covered by a top plate, the conduits lying between and substantially parallel to sidewalls, the sidewalls comprising a stack of a plurality of flat shims on the base plate, the shims of each stack being bonded together and the conduits and sidewalls being bonded to the base plate and top plate.

19. A heat exchanger comprising at least one layer of substantially parallel conduits, the layer lying on a base plate and being covered by a top plate, the conduits lying between and substantially parallel to sidewalls, the conduits of the layer being in a plurality of groups of conduits, adjacent groups being separated by a spacer bar extending substantially parallel to the sidewalls, the spacer bars and sidewalls being of the same height and the conduits, sidewalls and spacer bars being bonded to the top and bottom plates.

Am ndments to th claims have been filed as follows

20. A heat exchanger according to Claim 19, in which each spacer bar comprises a stack of a plurality of flat shims on the base plate, the shims of the stack being bonded together.

21. A heat exchanger according to Claim 19 or 20, in which the sidewalls comprise a stack of a plurality of flat shims on the base plate, the shims of the stack being bonded together.

22. A heat exchanger according to Claim 21, in which the spacer bar shims and sidewall shims are composite shim units.

23. A heat exchanger according to any one of Claims 19 to 22, in which the conduits are provided by a plurality of tubes.

24. A heat exchanger according to any one of Claims 20 to 23, in which the shims are formed of rolled sheet.

25. A heat exchanger according to Claim 24, in which the rolled sheet is of stainless steel, a nickel-based alloy, brass or copper.

26. A heat exchanger according to any one of Claims 20 to 25, in which the plates are rectangular and the shims are formed as rectangular annuli.

27. A heat exchanger according to any one of Claims 19 to 26, in which the base plate has corrugations and the conduits lie in the corrugations.

28. A heat exchanger according to any one of Claims 19 to 27, which has a plurality of layers of conduits and in adjacent layers, the conduits extend transversely to each other.

29. A method of making a heat exchanger comprising at least one layer of conduits, in which a layer of substantially parallel conduits is laid on a base plate, two sidewalls are positioned on the base plate with the conduits lying between them and substantially parallel to the

sidewalls, the conduits of the layer are positioned in a plurality of groups of conduits and a spacer bar of the same height as the sidewalls is positioned to extend parallel to the sidewalls and between two adjacent groups of conduits, a top plate is positioned on the structure so formed and heat and loading is applied to bond the structure together.

30. A method according to Claim 29, in which the height of the sidewalls and the spacer bar(s) is such that the conduits extend above them, the top plate is positioned to rest on the so-extending upper surfaces of the conduits and the heat and loading are applied in a vacuum to deform the conduits to reduce their height, whereby the conduits bond to the plates.

31. A method according to Claim 30, in which the conduits are initially tubes of circular cross-section and are deformed to oval cross-section during the bonding step.

32. A method according to Claim 31, in which the distance between the sidewalls is greater than the sum of the outside diameters of the tubes by an amount predetermined by calculation from the sum of the outside diameters such that the tubes of a group of conduits bond to each other as they deform during the bonding step.

33. A method according to any one of Claims 29 to 32, in which the spacer bars are built up from a plurality of flat shims.

34. A method according to any one of Claims 29 to 33, in which after a first layer of conduits has been positioned on the base plate together with the sidewalls and spacer bar(s), an intermediate plate is positioned on the structure, further conduits, sidewalls and spacer bar(s) are laid on the intermediate plate and the process is repeated to achieve the desired number of layers of conduits and the top plate is then added.

35. A method according to any one of Claims 29 to 34, in which the bonding is carried out under conditions to achieve diffusion bonding.

The Patent Office

23

Applicati n No: GB 9718542.5
Claims searched: 1-18

Examiner: T M James
Date of search: 29 January 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): B3A (A158): B3Q (Q3); F4S

Int Cl (Ed.6): B21C (37/22); B21D (53/08); B23P (15/26); F28D (1/03, 1/053): F28F (1/02, 3/12)

Other: On-line: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	GB 2312737 A	(IMI) see page 9 lines 4-9	-----
A	US 4024620	(Torcomian) see column 5 line 65 - column 6 line 13	-----

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		

The Patent Office

24

Application No: GB 9718542.5
Claims searched: 19

Examiner: Tim James
Date of search: 22 July 1998

Patents Act 1977
Further Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F4K (K25B, K25C, K25U, K25Z); F4S (S4JX)

Int Cl (Ed.6): F28D (1/03); F28F (1/02, 3/12)

Other: On-line: WPI; EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	US 4715431	(Schwarz & Kalb) see figure 8 items 108, 109, 200 and 210	19

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		